Smart Energy Systems

Holistic and Integrated Energy Systems for the era of 100% Renewable Energy

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Holistic and Integrated Energy Systems for the era of 100% Renewable Energy

Context

Energy systems are currently undergoing a transition from fossil fuels to renewable energy. This is occurring for a variety of reasons, which in an EU context includes:

- To reduce greenhouse gas emissions (GHG)
- To reduce imported fossil fuels
- To utilise local resources and create local jobs
- To reduce the costs of energy towards 2050

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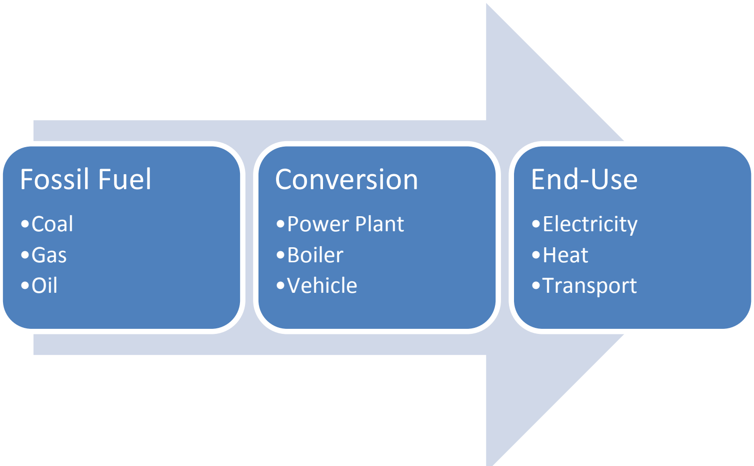
This transition faces many challenges from a variety of different perspectives, including:

- Technology: The development of new technologies and infrastructures, which will enable us to utilise renewable energy resources.
- Business: The design of new markets, products, services, and industries so that these new technologies can be implemented.
- Policy: The creation of new policy and institutions which will promote the most beneficial technologies for society, so that they are also the most profitable investments for these new businesses.

This brochure focuses on the Technology phase of this transition, by outlining how it will be possible to provide society using 100% renewable energy before 2050, at a lower cost than fossil fuels.

The Energy System of Today: Fossil Fuels



Today, the design of the energy system is based on fossil fuels. This makes the energy system very flexible and reliable since large amounts of energy can be stored in liquid, gas, and solid form via fossil fuels. This means that energy can be provided ‘on demand’, as long as there is a suitable fossil fuel storage nearby, such as a diesel tank in a car, a gas tank for a boiler, or a coal storage for a power plant. Hence, fossil fuels have provided society with a lot of flexibility: fossil fuels store large amounts of energy so it is available on demand whenever it is required. However, in the future this flexibility will be limited.

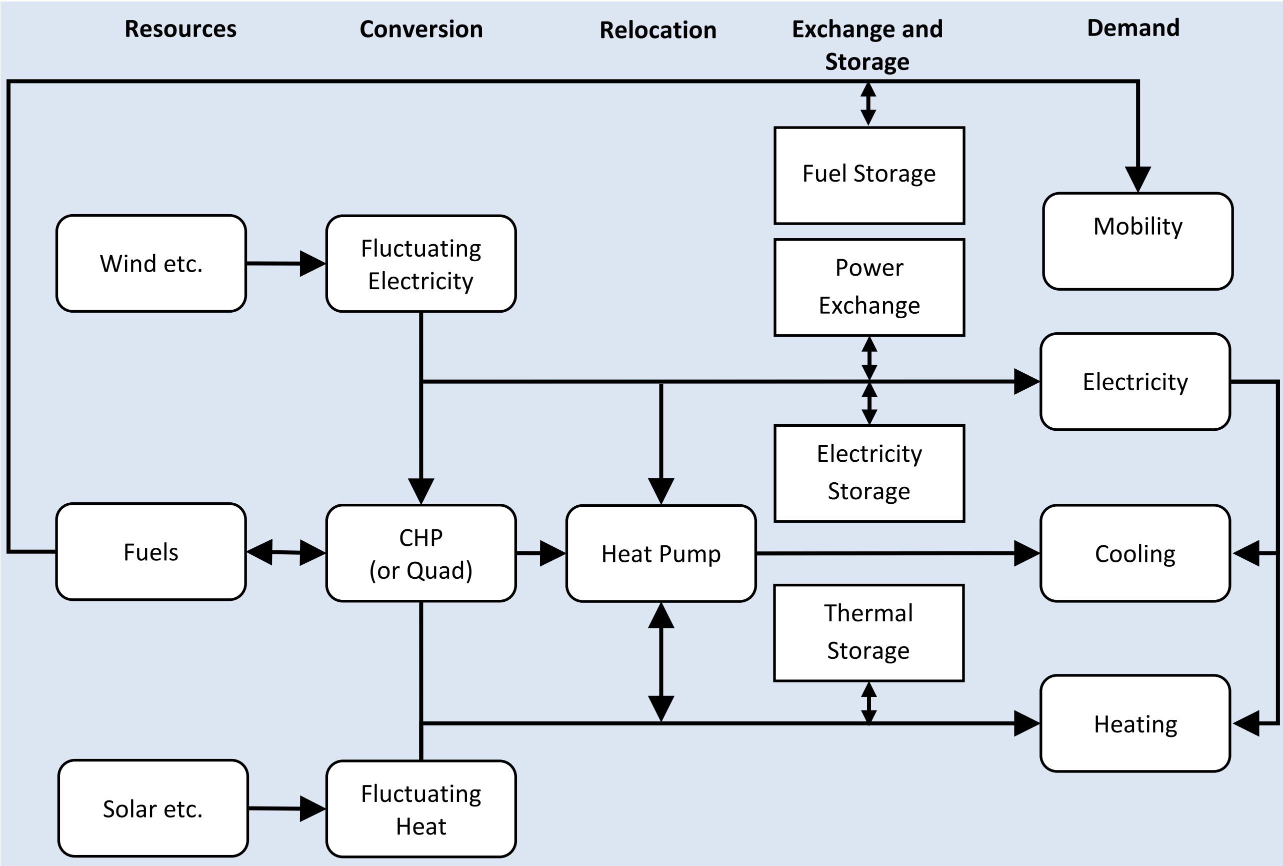
The Energy System of Tomorrow: 100% Renewable Energy

The future energy system will rely on renewable energy resources such as wind and solar power. These resources do not contain large amounts of stored energy, but instead the energy from the wind, sun, waves, and tides must be captured and used immediately. This is the key technological challenge facing energy systems in the future.

Challenge: How can the future energy system, which will be based on renewable energy, operate without the flexibility currently being provided by large amounts of stored energy in fossil fuels, while simultaneously providing affordable energy and utilising a sustainable level of the resources available?

Solution: The solution will be to find new forms of flexibility within the energy system, which are affordable and utilise renewable energy resources in an efficient manner. This is called a smart energy system.

The Smart Energy System



A smart energy system consists of new technologies and infrastructures which create new forms of flexibility, primarily in the 'conversion' stage of the energy system. This is achieved by transforming from a simple linear approach in today's energy systems (i.e. fuel to conversion to end-use), to a more interconnected approach. In simple terms, this means combining the electricity, thermal, and transport sectors so that the flexibility across these different areas can compensate for the lack of flexibility from renewable resources such as wind and solar. The smart energy system uses technologies such as:

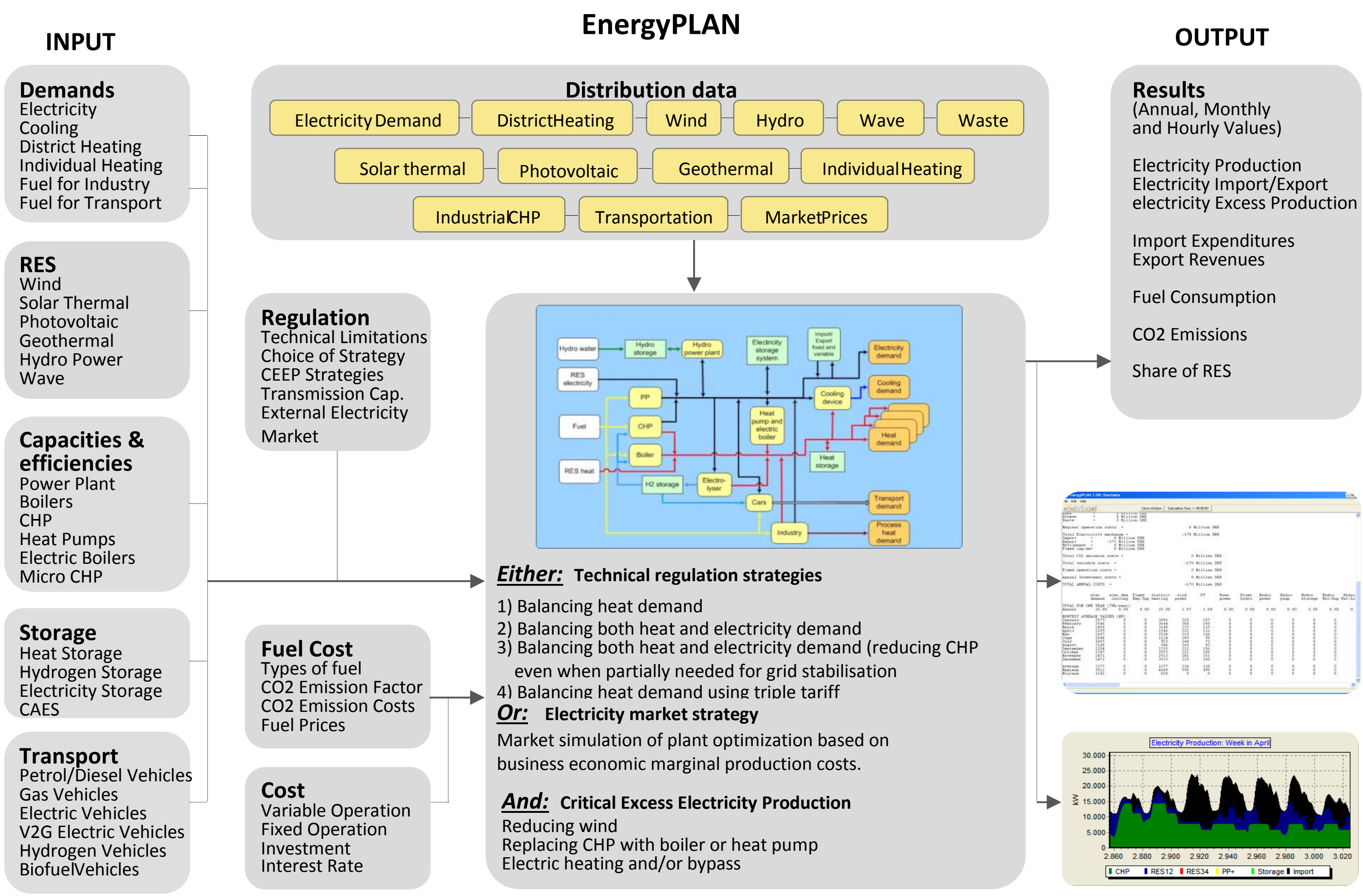
- **Smart Electricity Grids** to connect flexible electricity demands such as heat pumps and electric vehicles to the intermittent renewable resources such as wind and solar power.
- **Smart Thermal Grids** (District Heating and Cooling) to connect the electricity and heating sectors. This enables thermal storage to be utilised for creating additional flexibility and heat losses in the energy system to be recycled.
- **Smart Gas Grids** to connect the electricity, heating, and transport sectors. This enables gas storage to be utilised for creating additional flexibility. If the gas is refined to a liquid fuel, then liquid fuel storages can also be utilised.

In a stricter sense, these infrastructures can be defined as:

- **Smart Electricity Grids** are electricity infrastructures that can intelligently integrate the actions of all users connected to it - generators, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure electricity supplies.
- **Smart Thermal Grids** are a network of pipes connecting the buildings in a neighbourhood, town centre or whole city, so that they can be served from centralised plants as well as from a number of distributed heating or cooling production units including individual contributions from the connected buildings.
- **Smart Gas Grids** are gas infrastructures that can intelligently integrate the actions of all users connected to it - supplies, consumers and those that do both - in order to efficiently deliver sustainable, economic and secure gas supplies and storage.

Based on these fundamental infrastructures, a **Smart Energy System** is defined as an approach in which smart Electricity, Thermal and Gas Grids are combined and coordinated to identify synergies between them in order to achieve an optimal solution for each individual sector as well as for the overall energy system.

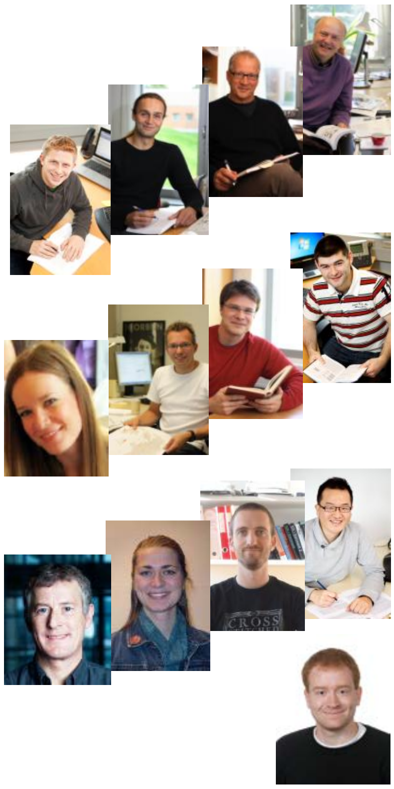
The advanced energy systems analysis model, EnergyPLAN, has been developed to model these smart energy systems on an hourly basis (www.EnergyPLAN.eu), so that optimal solutions can be identified. The results verify that with these smart grids in place, it is possible to transform to 100% renewable energy systems by 2050, based on sustainable resources and while providing energy at the same price as fossil fuels.



Who are we?

The Smart Energy System definitions presented here and the EnergyPLAN model are developed by the Sustainable Energy Planning Research group at Aalborg University. The research group studies energy planning and management in an interdisciplinary perspective. Focus is placed on energy planning in relation to technological, geographical, economic, and institutional conditions. The research conducted can be divided into three main areas of study:

- Energy System Analysis
- Feasibility studies
- Public regulation viewed in the light of technological change



Some key publications in relation to smart energy systems include:

- Lund H, Andersen AN, Østergaard PA, Mathiesen BV, Connolly D. From electricity smart grids to smart energy systems - A market operation based approach and understanding. Energy 2012;42(1):96-102.
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- Lund H, Hvelplund F. The economic crisis and sustainable development: The design of job creation strategies by use of concrete institutional economics. Energy 2012;43(1):192-200.

You can read more about our research, the EnergyPLAN model, and our Master's degree in Sustainable Energy Planning and Management on our website, www.EnergyPLAN.eu.